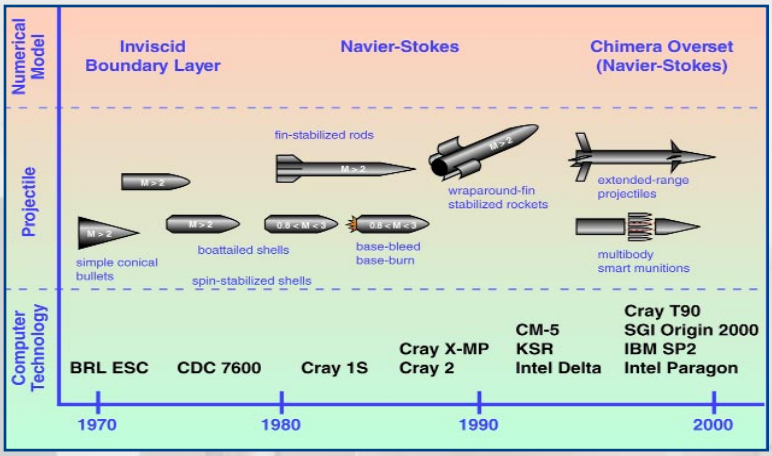
U.S. Army Research Laboratory

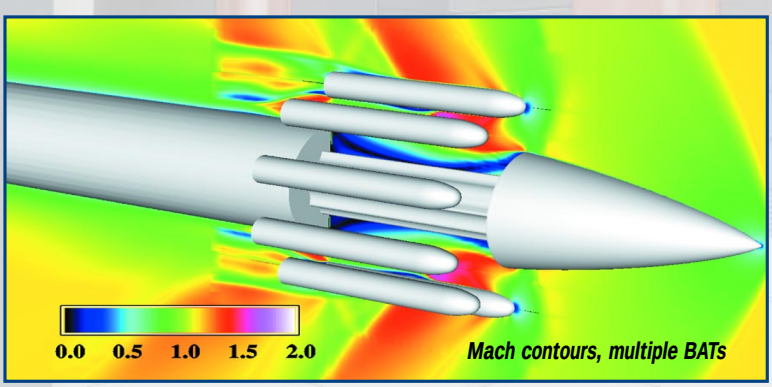
COMPUTATIONAL FLUID DYNAMICS OF MILITARY SYSTEMS

Understanding the aerodynamics of projectiles, rockets, and missiles is critical to the design of stable configurations and contributes significantly to the overall performance of weapon systems. A critical technology for understanding and predicting the aerodynamic behavior of projectiles is Computational Fluid Dynamics (CFD). The Aerodynamics Branch of the U.S. Army Research Laboratory (ARL) has successfully applied CFD to the development of numerous U.S. Army projectile and missile-based weapon systems. ARL's advanced CFD capability is further enhanced through the application of high performance computing resources at the DoD Major Shared Resource Center (Aberdeen Proving Ground).

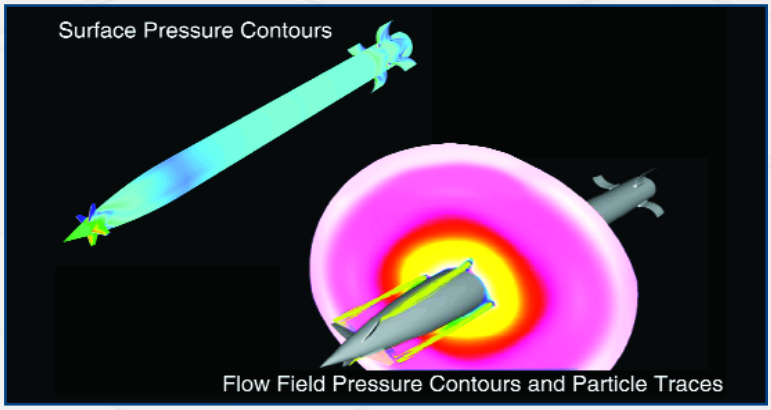
Current CFD modeling relies on steady and unsteady Navier-Stokes solvers to predict the flight performance of projectiles and missiles in all speed regimes. A mature capability exists to predict the aerodynamics of spin-stabilized artillery shells and fin-stabilized kinetic-energy projectiles. Research efforts have examined the aerodynamics of wraparound fin designs for tube-launched artilleryprojectiles and the aerodynamic performance of projectiles traveling at hypervelocity. Additionally, work is ongoing in the aerodynamics of multiple-body systems with highly separated flows, such as submunition ejection from missiles while in flight.



Evolution of State-of-the-Art Computational Projectile Aerodynamics

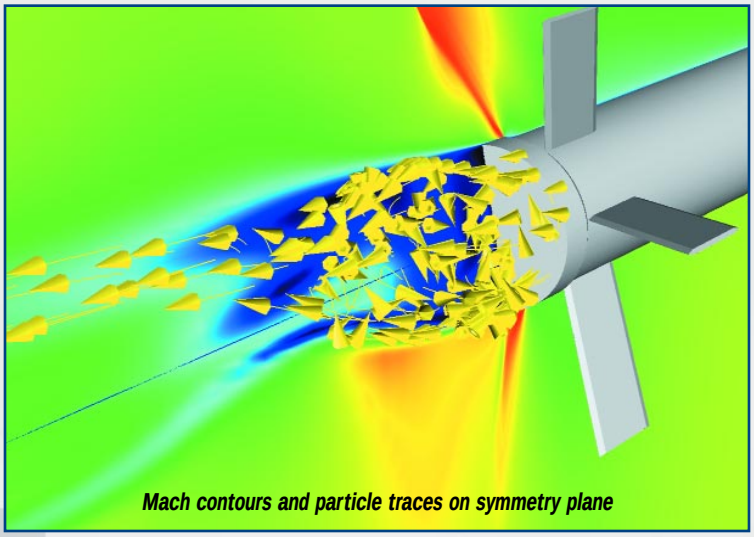


Army Tactical Missile System (ATACMS) Brilliant Antiarmor Munition (BAT) Submunition Dispense



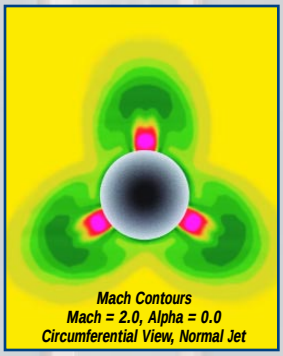
Aerodynamics of Extended-Range Projectile Guided Multiple Launch Rocket System (MLRS) Showing Effects of Forebody Canards on Rear Fins

New CFD capabilities are being developed to predict the control aerodynamics of smart munitions, missile, and rocket systems. Current research is focused on the prediction of aerodynamics of control devices such as canards and reaction jets. The reaction-jet and canard work supports the XM982 (cannon artillery projectile), 2.75" Low-Cost Precision Kill (rocket), Low-Cost Competent Munitions (cannon artillery projectiles), Guided Multiple Launch Rocket System—Guided MLRS (rocket), and Tank Extended-Range Munition—TERM (tank kinetic-energy projectiles) programs. These CFD developments will be integrated to create a multidisciplinary design capability for complex U.S. Army smart munitions systems. Initial efforts have coupled CFD with rigid body flight dynamics. Structural vehicle response, propulsion, guidance, navigation, and control will be integrated in the future to develop a comprehensive CFD-based design and evaluation capability.



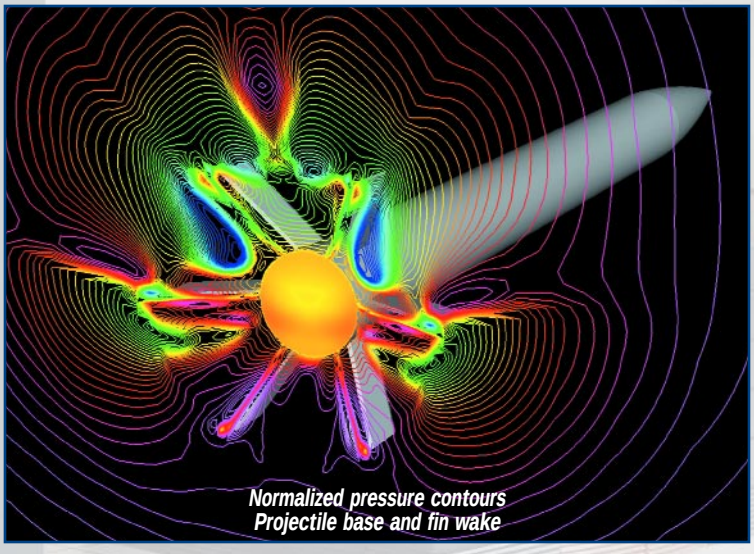
Mach contours and particle traces on symmetry plane

Mach Contours
Mach = 2.0, Alpha = 0.0
Normal Jet



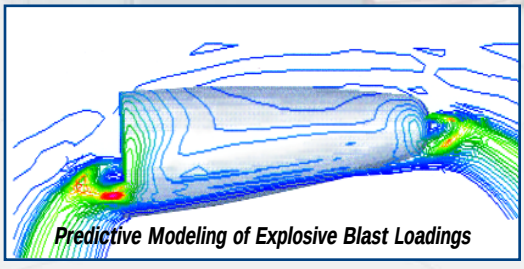
Mach Contours
Mach = 2.0, Alpha = 0.0
Circumferential View, Normal Jet

Reaction-Jet Control of Smart Maneuvering Munitions



Normalized pressure contours
Projectile base and fin wake

Extended-Range Projectile



Predictive Modeling of Explosive Blast Loadings

CFD techniques are also being developed to address the aerodynamic aspects of Active Protection countermunitions launched against anti-armor projectiles. The current effort investigates the aerodynamic interaction of a kinetic-energy projectile with the blast produced by a detonating-warhead countermunition. Application of CFD in this area will provide the technology to optimize the design of Active Protection systems and a means of assessing the effectiveness of potential countermunitions.

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